Physics for future Presidents

Department of Physics, Carnegie Mellon, Fall 2019, Deserno

Homework 8 *Calculations* are due in class on Wednesday, Oct. 2nd
Draft of the essay is due in recitation on Thursday, Oct. 3rd
Finalized essay is due the next day, in the lecture on Friday, Oct. 4th

---

The Fukushima Daiichi nuclear accident

The Tōhoku earthquake and tsunami that hit Japan on March 11, 2011 caused devastating damage. In this assignment, you will write an essay that deals only with the difficulties associated with the cooling of the Unit 1 reactor at the Fukushima Daiichi power plant. *Before writing your essay, you should perform the following calculations and hand them in on Wednesday*:

1. The Unit 1 reactor was a "boiling water" type reactor. These reactors generally work under high pressure and produce steam at temperatures around $380\,\mathrm{C}$. The power plant is a "heat engine", so some of this thermal energy is released to the atmosphere and some is converted to electrical power. Use the efficiency equation from chapter 2 (page 60) to estimate the maximum possible efficiency for this reactor.

2. The Unit 1 reactor was capable of producing $460\,\mathrm{MW}$ of *electrical* power. Assuming that the plant's efficiency was about 10% less than the optimal efficiency you found in the previous question, what was the *thermal* power output (in units of MW) of the reactor?

3. The reactor was shut down quickly after the earthquake struck, and hence the nuclear chain reaction was halted. However, the highly radioactive fission fragments within the reactor continued to decay and thus produce heat (the so-called "decay heat"). Combine your estimate of the thermal output during normal operation with the information in your textbook (see text above Fig. 5.13) to estimate the thermal output of the reactor just after the shutdown and one year after the shutdown.

4. Heat can be removed from the reactor complex by allowing it to boil water. The process of boiling off a gallon of water that is initially at $20\,\mathrm{C}$ takes approximately $9.8 \times 10^6\,\mathrm{J}$ (or $9.8\,\mathrm{MJ}$) . Combine this information with your previous work to compute the rate that water must be supplied (in gallons per second or gallons per minute) to carry away the heat so the reactor does not heat up and melt. Remember that a Watt is a Joule per second, or $\mathrm{W} = \mathrm{J/s}$.

Once you have completed these calculations, you should write your essay on the following topic:

Discuss the difficulties encountered with keeping the reactor cool after the earthquake, even though it had been shut down. Work at least some of the numbers you have calculated into your essay.